6th International Scientific Conference
May 13–14, 2010, Vilnius, Lithuania
BUSINESS AND MANAGEMENT 2010
Selected papers. Vilnius, 2010

ISSN 2029-4441 print / ISSN 2029-428X CD
doi:10.3846/bm.2010.147
http://www.vgtu.lt/en/editions/proceedings
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NEW CO-OPETITION APPROACH FOR SUPPLY CHAIN APPLICATIONS AND THE IMPLEMENTATION A NEW ALLOCATION RULE

Harald D. Stein[1], Romualdas Ginevičius[2]

Vilnius Gediminas Technical University, Sauletekio av. 11, LT-10223 Vilnius, Lithuania
E-mail: [1]hd.stein@web.de, [2]romualdas.ginevicius@vgtu.lt

Abstract. The paper introduces a new co-opetition approach in order to depict and analyze business relationships. An extended industrial supply chain is introduced where it is distinguished between individual customers and mass markets on the one side and on the other side between actually participating and potential customers. For each supply chain it is shown, with which game theoretic model the allocations can be calculated, considering stability, Pareto-efficiency and symmetry. It is shown in how far the several allocation rules like the Shapley-value, the Myerson-value, the Aumann-Drèze-value and the "outside-option modified value for coalition structures" can be used in order to predict negotiation outcomes and to achieve stable agreements.

Keywords: co-opetition, game theory, supply chains, backward-induction, allocation rules.

1. Introduction

In contemporary business literature, either competition or cooperation has been investigated in a one-sided way. The concurrency of both aspects has been mostly neglected. Co-opetition is the attempt to develop an integrative bridge between both aspects and to provide an advanced and more realistic theoretical point of view on business relationships. Due to the fact that game theory also assumes the ambivalence of competition and cooperation, it can be applied in co-opetition related problems. However, there is no generally accepted definition for co-opetition so far and it is not clear yet, how a co-opetition model may look like for a certain problem concerning business relationships.

In the paper a new definition of co-opetition is introduced. Therefore the "extended industrial supply chain" is developed. It is shown, how game theory is used for the prediction of negotiation outcomes in 3 agents' networks. A new allocation rule is developed. It is named as the "outside option modified allocation rule for coalition structures". It is shown in which cases the new allocation rule and where the older Aumann-Drèze-value are relevant, in order to reach stable agreements.

The goal is to contribute to a deeper understanding of business relationships under the aspect of concurrency of competition and cooperation.

The problem is approached deductively, i. e. theoretically and based on older literature. The co-opetition definition is connected with the most important literature of the older purely competitive or cooperative approaches. The "extended industrial supply chain" also is refered to older literature. The new allocation rule and question of agreement stability are based on approaches of game theory.

2. Definition of the co-opetition approach

Co-opetition is the situation in business relationships, in which competition and cooperation take place concurrently.

Co-opetition is the set of business models where the competitive business perspectives, like of Schelling (1960) and Porter (1980), the ransacttion costs economics (Spence 1973; Williamson 1975; Stiglitz 1975) and the principal-agent-theory (Jensen 1976) on the one side and the cooperative business perspective (Contractor, Lorange 1988), are combined to a new integrative perspective. Game theory can be used as mathematical instrument, e.g. by the implementation of negotiation theory or allocation rules, in order to depict or analyse the business relationships inside of supply chains, among invividual agents or towards mass markets.

The most successful contribution so far has been the book "Co-opetition" by Nalebuff and Brandenburger (1996). However it has fundamental structural and methodological flaws. Dagnino and Padula (2002) have made an important contribution in the formulation of co-opetition as integrative bridge between the purely competitive and the purely cooperative points of view. However, they do not show sufficiently the boundaries of co-opetition and the connection to game theory as the tool for the formalization. Other authors delve into particular problems that are connected with co-opetition like multinational enterprises (Luo 2004; Luo 2006) and agreements under incomplete information (Bakshi, Kleindorfer 2008).

3. Basic elements of a co-opetition approach

After Shubik, an economic "model is defined by its boundaries" (1982). Reality is simplified and the level of details is determined appropriately in accordance to the given problem. The level of details depends on simplifications that are reached by:

– approximation,
– symmetrization and
– aggregation.
– A co-opetition model is determined by the
– institutions (systems of rules),
– industrial boundaries: the product/service (content and distribution)
– industrial boundaries: the agents (as part of an "extended" industrial supply chain)
– time (dynamic setting)

The tremendous increase of complexity in particularly in network game theory is confirmed by Pin (Pin 2005). He states that the network games are "deep in the complexity class NP-hard". Therefore the paper is restricted to "extended" industrial supply chains with 3 agents.

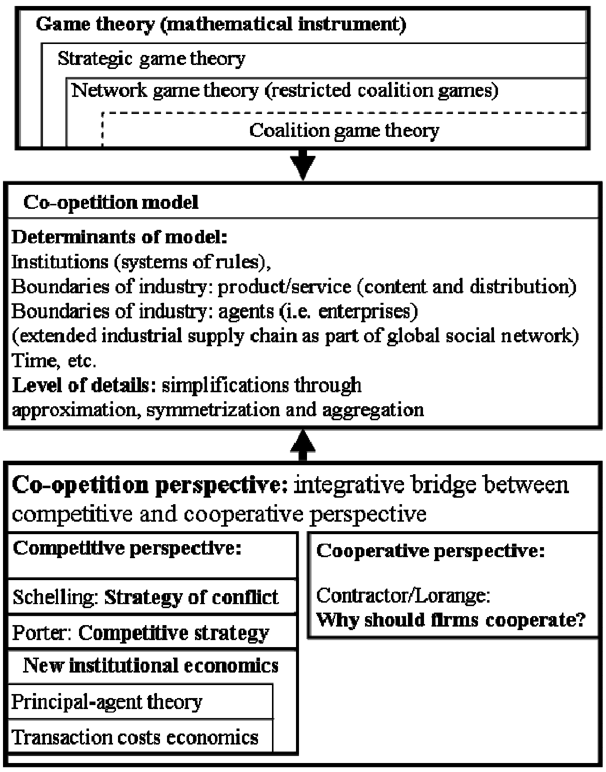


Fig. 1. Co-opetition overview

Time is another crucial element of a co-opetition model. Generally, each relationship or transaction is limited by time. Thus there are

– unique and irrevocable decisions (one shot),
– dynamic setting,
– with or without known end point and
– with high or low renegotiation costs.

Game theory is used as mathematical tool to formalize and solve co-opetition related problems. Game theory is the theory of strategic decisions of two or more mutually dependent agents (Vega-Redondo 2003). It is assumed that the agents intend to act rationally but their capabilities to do this are bounded (Simon 1994; Rubinstein 1998). Cooperation is possible, as soon as it is mutually the best decision. Therefore cooperation is regarded as a subform of competition and both terms are closely connected (Bernheim, Peleg 1987).

Figure 1 shows co-opetition as a model based on the co-opetition perspective that is an integrative bridge between the competitive perspectives and the cooperative counter-perspective in economic science on business relationships with game theory as a mathematical instrument.

4. The extended industrial supply chain

Figure 2 shows the "extended industrial supply chain". It depicts an enterprise in the relationship with other enterprises in the business environment and is an advancement of Porter's "5 forces driving competition" or N/B's "value net" (Porter 1980). It shows next to the

– actually participating agents (the "ego-agent" with the suppliers, customers, competitors and complementors)
– the potentially participating agents.

They have the possibility of entering the game and therefore are strategically relevant. Due to the fact that an industrial supply chain may consist of several steps, it can be distinguished between retailers (possibly a chain of retailers) and end-customers on the one side, and on the other side between suppliers, pre-suppliers, etc. The end customers can be aggregated, i. e. they represent mass markets. The individual agents may also represent more than one agent, if they symbolize a coalition or network. Coalitions and networks can be depicted as individual agents that talk "with one voice" or decide monolithically (Nouveland 2003; Jackson 2003a; Jackson 2003b; Wiese 2005). Individual and aggregated agents are treated in different ways:

– With individual agents it is possible to negotiate.
– With aggregated agents, negotiations are impossible or too costly. Instead, the suppliers anticipate the customers' reactions and decide based on that, the principle of backward induction.

In Figure 2, competitors are not linked despite of their cooperation possibilities.

In a mass market a supplier concludes a large number of single contracts with customers. Negotiations are usually not possible because the transaction costs would become too high in relation to the values of the single deals.

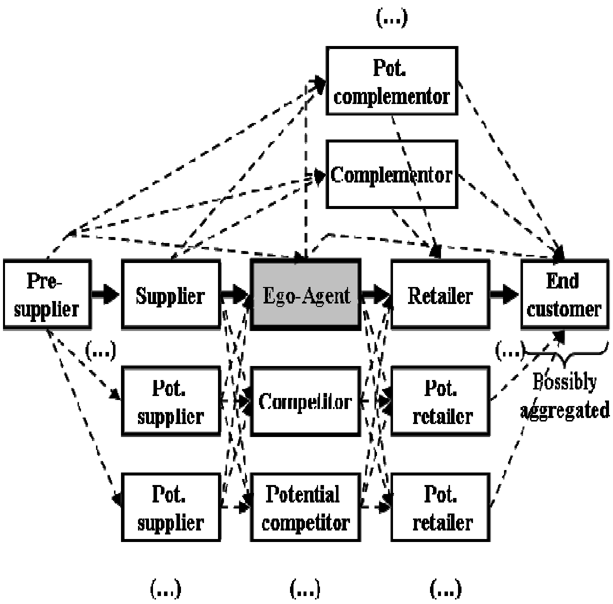


Fig. 2. "Extended" supply chain with (potential) suppliers, customers, competitors and "complementors", individual customers and mass markets

3 agents can build supply chains in several ways. The supply chains can be of 2 stages (supplier – customer) or 3 stages (pre-supplier – supplier – customer). In 2-stage supply chains the suppliers can be competitors or complementors. The customers can be individuals or aggregated (mass markets). Figure 3 shows the set all possible supply chains with 3 agents. The suppliers can be complementors or competitors.

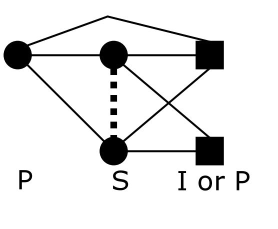
Set of all 3 agents' supply chains	
	**P:** Pre-supplier **S:** Supplier (suppliers either complementors or competitors) **I:** Individual customer **M:** Mass market

Fig. 3. Set of all supply chains with 3 agents, with individual customers or mass markets

The possible supply chains can be subdivided into those where there are:

– mass markets as customers,

– 3 stages with an individual customer and

– 2 stages with individual customers.

Figure 4 shows examples for each of the categories:

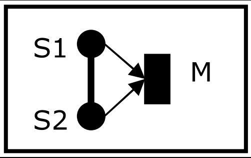
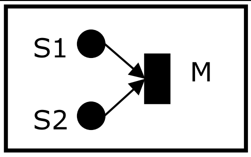
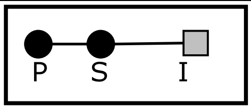
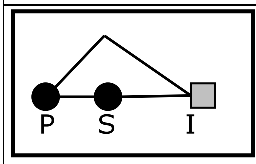
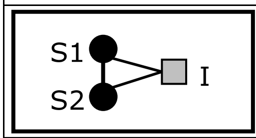
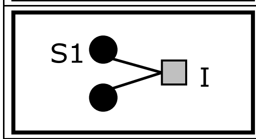
	Supply chain with 2 connected suppliers and one mass market
	Supply chain with 2 connected suppliers and one mass market. Suppliers are not connected, classical Cournot and Bertrand models
	Supply chain with a pre-supplier, a supplier and an individual customer. The pre-supplier and the individual customer are not connected and therefore depend on the supplier
	2 overlapping supply chains. Direct connection between pre-supplier and individual customer and supply chain P-S-I
	Supply chain with 2 connected suppliers and one individual customer
	Supply chain with 2 non-connected suppliers and one individual customer

Fig. 4. Examples of supply chains with mass markets as customer, with 3 stages and an individual customer and with 2 stages and an individual customer

5. Outside option modified value for allocation rules

A new allocation rule is developed that considers the outside option, i. e. the impact of the excluded agent in the case of unbalanced 3 agent networks. It is shown that if the (restricted) grand coalition does not provide any profit, there is no difference between whether the suppliers are connected or not. If it is possible for the principal to switch the agent, it is a permanent situation of negotiation. Therefore the new allocation rule has to imply the permanent auction that takes place among the suppliers. The principal has to select 1 from 2 agents in order to establish the cooperation. Therefore he compares the outcomes of the alternatives. In dynamic setting, these outcomes are summarized (and discounted) over the rounds to the net present value.

The agents iteratively "improve" their bids in the eyes of the principal and thereby approach the reservation bid (maximal offer) of the second-best bidder (Steimle 2008). Therefore, the reservation bid of the second-best bidder becomes public information. This is the same for both the first-bid and second-bid auctions (Vickrey 1961). However the reservation bid of the best bidder is in general his private information. Here it is assumed that the reservation bid of the best bidder is public information as well.

As soon as the strongest bidder makes an offer that exceeds the reservation bid of the second-best bidder, this second-best bidder leaves the auction. The agreement between the principal and the strongest bidder cannot be blocked any more. Therefore each agreement in this area is a coalition-proof Nash-equilibrium (CPNE) (Bernheim, Peleg 1987; Moldovanu 1992). From the point of view of the principal, the added value of the strongest bidder is the difference between the best and the second-best bid. This added value is divided symmetrically. This is the idea of the "outside-option modified value for coalition structures (OOCS-value)".

In the style of Myerson's axiomatization of the Shapley value (Shapley 1953; Shapley 1967; Shapley 1970; Myerson 1980), the OOCS-value is defined by the axioms:

Component-Pareto-efficiency:

$$\sum_{i\in C} OOCS(N,v,g) = v(C) \quad (1)$$

for the productive component

– Modified axiom of balanced contributions:

The modification of the axiom of balanced contributions consists of a pre-stage, where the winning cooperation partner transfers the value of the loosing cooperation partner to the main agent. Afterwards the balanced contributions axiom is used in the usual way. Thus:

1. For the agents $A,B,C \in N$: if *A* has to select the cooperation partner and $v(AB) > v(AC)$, then A selects B and first demands the amount: $v(AC)$ by agent *B*.

2. Afterwards the contributions are balanced:

$$OOCS_A(N,v,g) - OOCS_A(N,v,g\setminus\{B\}) = OOCS_B(N,v,g) - OOCS_B(N,v,g\setminus\{A\}) \quad (2)$$

3. So that A and B divide the difference of B's and C's offer equally.

In a coalition structure, the OOCS-value provides for $v(AB) > v(AC)$:

$$OOCS-value = \left(\frac{v(AB)+v(AC)}{2};\frac{v(AB)-v(AC)}{2};0\right) \quad (3)$$

In comparison, the AD-value and Myerson-CS-value provide:

$$AD-value = Myerson-CS-value = \left(\frac{v(AB)}{2};\frac{v(AB)}{2};0\right) \quad (4)$$

The net present values can be entered into the referring places of the coalition functions:

$$v(U,S_1) = NPV_{U;1} \; v(U,S_2) = NPV_{U;2} \quad (5)$$

The calculation of the maximal concession is trivial. Each agent can maximally propose his complete NPV of the project. However, the calculation of the minimal concession requires an exact distinction, which potential supplier gives the offer for E. This means for S1, he wins the auction if his NPV is higher. Therefore he needs to exceed his competitor's maximal concession just marginally. For instance, the marginal value is just 1 Euro-Cent. Then, the other potential supplier cannot compete any more and the area of S1's added value begins.

The weaker supplier knows from the beginning that he is going to lose. However the offer of the complete NPV is the result of the bidding iterations and therefore represents both the minimal and the maximal offer.

Table 1. Minimal, maximal offers of the potential suppliers in dependence of the respective other supplier

Pespective	*Condition*	*Minimal offer*	*Maximal offer*
S_1	$NPV_1 \succ NPV_2$	$NPV_2 + x$	NPV_1
	$NPV_2 \geq NPV_1$	NPV_1	
S_2	$NPV_2 \succ NPV_1$	$NPV_1 + x$	NPV_2
	$NPV_1 \geq NPV_2$	NPV_2	

The minimal and maximal offers of the winning bidder are both the end points of the respective core. The OOCS-value (and 2-agents' Shapley-value) is the arithmetic average. This is the consequence of the *modified* symmetry axiom.

For different characteristic functions the tables 2-6 show the minimal bids, maximal bids and the OOCS-values. In table 2, the resulting OOCS-value is: $OOCS-value = (10;10;0)$

In Table 3 the OOCS-value that results from the characteristic function with

v(P ; S_1) = 20 and

v(P ; S_2) = 10 is:

$OOCS-value = (15;5;0)$.

In Table 4 the OOCS-value that results from the characteristic function with:

v(P ; S_1) = 20 and

v(P ; S_2) = 20 is:

$$OOCS - value = (20;0;0).$$

Table 2. Minimal, maximal bids, "outside-option modified allocation-rules for coalition structures (OOCS)", if the profit through the cooperation with S_1 is 20 and with S_2 is 0

NPV		v(P ; S_1)	v(P ; S_2)
		20	0
Min. bid: S_1 / S_2 *to* P	P	0.01	0
	S_1	19.99	–
	S_2	–	0
Max. bid: S_1 / S_2 *to* P	P	20	0
	S_1	0	–
	S_2	–	0
OOCS	P	10	0
	S_1	10	–
	S_2	–	0
Δ *bids to* P		10	–

Table 3. Minimal, maximal bids, "outside-option modified allocation-rules for coalition structures (OOCS)", if the profit through the cooperation with S_1 is 20 and with S_2 is 10

NPV		v(P ; S_1)	v(P ; S_2)
		20	10
Min. bid: S_1 / S_2 *to* P	P	10.01	10
	S_1	9.99	–
	S_2	–	0
Max. bid: S_1 / S_2 *to* P	P	20	10
	S_1	0	–
	S_2	–	0
OOCS	P	15	10
	S_1	5	–
	S_2	–	0
Δ *bids to* P		5	0

Due to the fact that the offers of both agents are identical, the principal has all negotiation power. The suppliers lose all negotiation power.

In table 5 the OOCS-value that results from the characteristic function with

v(P ; S_1) = 20 and

v(P ; S_2) = 30 is:

$$OOCS - value = (25;0;5).$$

Supplier 2's offer has become superior and obtains the agreement. However, due to the fact that S_2 offer is just slightly higher than that of S_1, the principal obtains the vast part of the profit.

Table 4. Minimal, maximal bids, "outside-option modified allocation-rules for coalition structures (OOCS)", if the profit through the cooperation with S_1 is 20 and with S_2 is 20

NPV		v(P ; S_1)	v(P ; S_2)
		20	20
Min. bid: S_1 / S_2 *to* P	P	20	20
	S_1	0	–
	S_2	–	0
Max. bid: S_1 / S_2 *to* P	P	20	20
	S_1	0	–
	S_2	–	0
OOCS	P	20	20
	S_1	0	–
	S_2	–	0
Δ *bids to* P		0	0

Table 5. Minimal, maximal bids, "outside-option modified allocation-rules for coalition structures (OOCS)", if the profit through the cooperation with S_1 is 20 and with S_2 is 30

NPV		v(P ; S_1)	v(P ; S_2)
		20	30
Min. bid: S_1 / S_2 *to* P	P	20	20.01
	S_1	0	–
	S_2	–	9.99
Max. bid: S_1 / S_2 *to* P	P	20	30
	S_1	0	–
	S_2	–	0
OOCS	P	20	25
	S_1	0	
	S_2	–	–
Δ *bids to* P		0	-5

Table 6 shows the case with S_1 is 20 and with S_2 is 40. Still, the principal strongly profits of S_1 as outside option.

Table 6. Minimal, maximal bids, "outside-option modified allocation-rules for coalition structures (OOCS)", if the profit through the cooperation with S_1 is 20 and with S_2 is 40

NPV		v(P ; S_1)	v(P ; S_2)
		20	40
Min. bid: S_1 / S_2 *to* P	P	20	20.01
	S_1	0	–
	S_2	–	19.99
Max. bid: S_1 / S_2 *to* P	P	20	40
	S_1	0	–
	S_2	–	0
OOCS	P	20	30
	S_1	0	–
	S_2	–	10
Δ *bids to* P		0	-10

6. Stability of agreements in dependence of the renegotiation possibility, agent switching costs and private information

If renegotiations are not possible, it is a static model. The allocation rules in dependence of weather the suppliers are connected or not and weather (restricted) grand coalitions are possible or not, are shown in Figure 5:

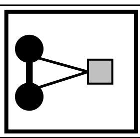
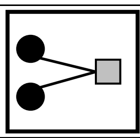
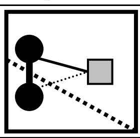
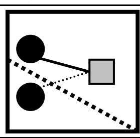
	Suppliers connected	*Suppliers non-connected*
(Restricted) grand coalition		
	Shapley-value	Myerson-value
(Restricted) coalition structure		
	OOCS-Value	OOCS-Value

Fig. 5. Allocation rules for 3-agent supply chains for the cases that renegotiations are not possible

In the case of unrestricted grand coalitions the Shapley-value is used. In the case of restricted grand coalitions the Myerson-value is applied. If there are coalition structures (each grand coalition can be blocked by a subcoalition) and if renegotiations are possible, it can be distinguished between

– high agent switching costs and
– low agent switching costs.

High agent switching costs: If the costs of switching the agent are high the distinction between

– ex ante (before the contract conclusion) and
– ex post (after the contract conclusion) is important.

The ex ante phase seems to be very similar with the case of low switching costs. The principle of the OOCS-value seems to be valid. Both agents "improve" their offers until the stronger agent gains the contract and the added value is distributed equally. However, ex post, the principal cannot change switch to the other agent. Through the exclusion of the weaker agent, the negotiation power changes instantaneously. This change is anticipated to the ex ante phase (Fig. 6).

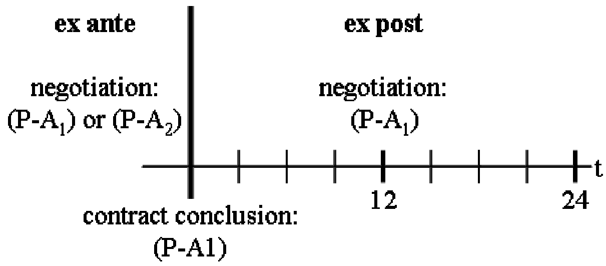


Fig. 6. Network with 1 demander (ego-agent) and 2 non-connected suppliers, allocation rules for balanced and non-balanced characteristic network functions, high and low switching costs

With high switching costs, the AD-value is used and provides the solution:

$$AD = \left(\frac{v(\{A;B\})}{2}, \frac{v(\{A;B\})}{2}, 0 \right) = \left(\frac{1}{2}, \frac{1}{2}, 0 \right) \text{ (normalized)}$$

The balance of power changes through the negotiation. If the renegotiation costs are low, it can be regarded as a permanent "ex ante situation". This is shown in Figure 7:

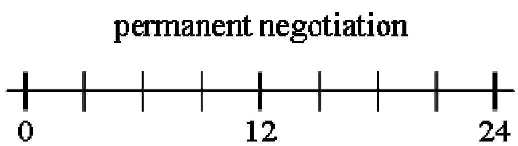


Fig. 7. Low switching costs

Each agreement that is not the PCore (here equal to the core), can be blocked by an alternative subgroup. The excluded agent C remains at the bargaining table as the "outside option". Time-inconsistency steadily endangers the agreement. However "small changes" to not lead to a breach of contract as the allocation that is proposed by the OOCS-value in is the middle of the PCore (core). Thus, an agreement that follows the OOCS-value is not necessarily stable over the whole time of the cooperation. However being a coalition-proof Nash-equilibrium neither the bindingness of the agreement is required, nor that the agents mutually impute rationality.

In the case of low switching costs, it must be considered that the customer can switch his supplier at any time. Therefore the second-best supplier serves as the outside-option. Therefore, the outside-option-modified allocation rule for coalition structures (OOCS-value) is used. For the characteristic function $v = (0;0;0;60;30;0;60)$ the allocation is:

$$OOCS - value = (45;15;0)$$

If the agent switching costs are low, the excluded agent has an enormous impact on the game. The principal gains the arithmetic average of both maximal bids (OOCS-value) and during the whole period the situation of "negotiation" prevails. If the second-best bidder lowers his offer, the actual agent can claim a bigger share.

7. Conclusions

A new definition of co-opetition has been presented. It has been defined as an integrative perspective of the pure competitive and the purely cooperative approaches in the literature of business relationships. Possible determinants of a co-opetition model have been described. The most important deperminants are

– institutions (systems of rules) like companies, the state or culture,

– the industrial boundaries like the product/service (content and distribution), the agents (as part of an "extended" industrial supply chain) and

– time if the setting is dynamic.

The paper has introduced the "outside-option modified allocation value for coalition structures (OOCS-value)". It is the the result of an auction with 2 bidders, where the demander gains the average of the reservation prices of the bidders and the winning bidder gains the half of the difference of the reservation prices. The outside-option representing agent does not gain anything despite of his influence on the allocation.

The stability of agreements has been been investigated. In the case of unrestricted grand coalitions the Shapley-value is applied. In the case of restricted grand coalitions the Myerson-value is used. In the case of coalition structures and if renegotiations are possible, it can be distinguished between high agent switching costs and low agent switching costs. If the agent switching costs are high, the Aumann-Drèze-value is appropriate that is equivalent to the Myerson-value for coalition structures in the case of 3 agents. If it is low, it is a permanent ex-ante situation and the OOCS-value is relevant.

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